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# Design Approaches for the Bed of Nails Technique

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*Org. 1647 – Solid Dynamic Experiments*

*-Shock Thermodynamics Applied Research Facility - (STAR)*



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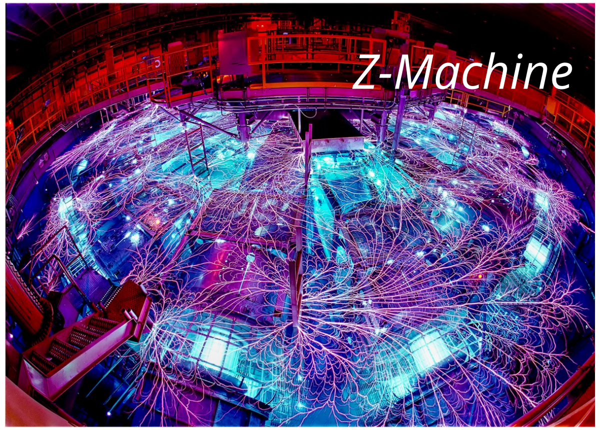
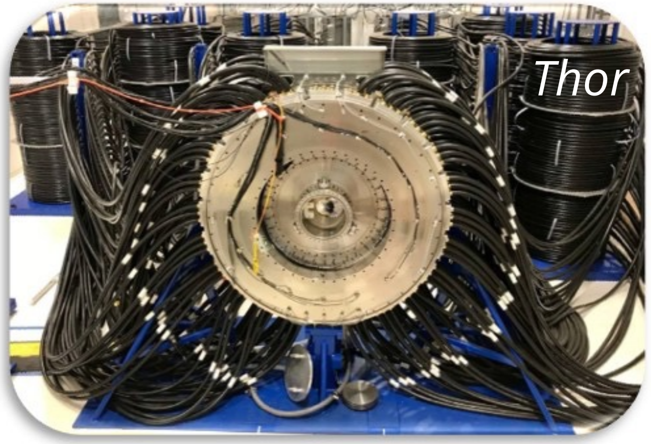
SAND2022-9545 C

# Isentropic (Ramp) Loading

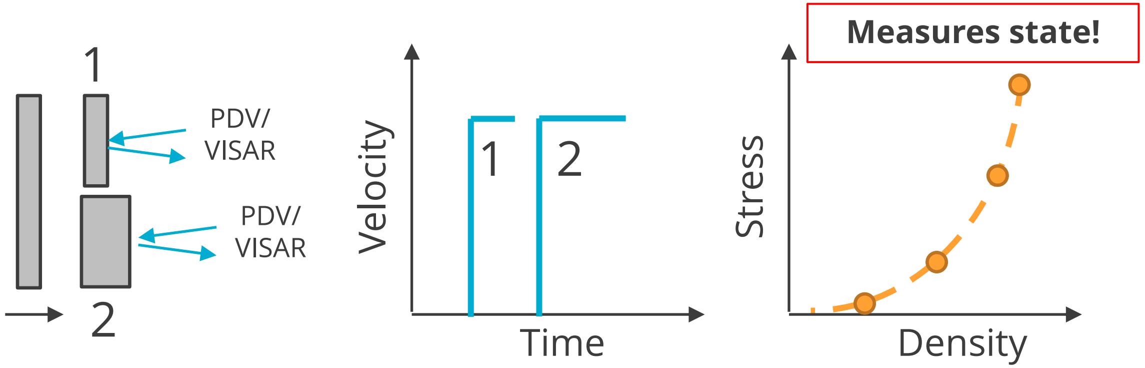


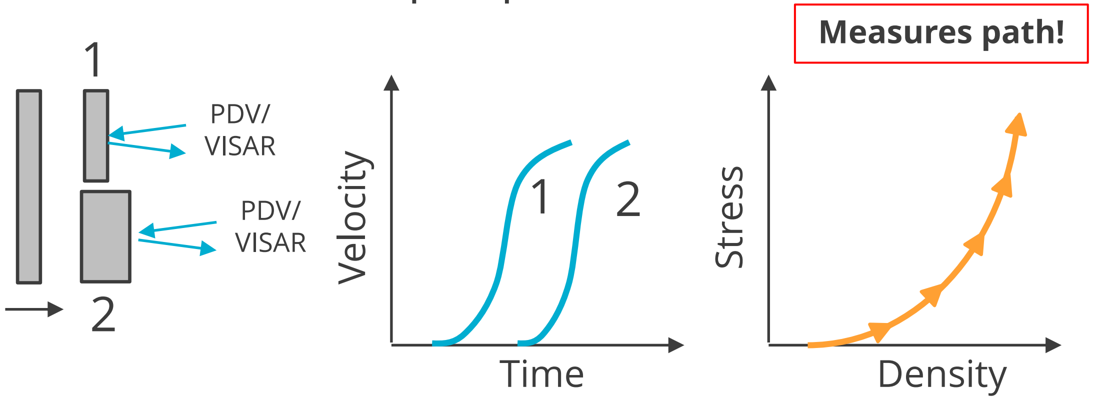

- Sandia's pulsed power techniques & relevance for high pressure EOS development
- Shock vs. ramp loading
  - Hugoniot/Off-Hugoniot and entropy differences
- Limitations of existing platforms

- Research Question:
  - Can we develop an analog to pulsed power or laser approaches that can be used for gas guns?

Shock experiments



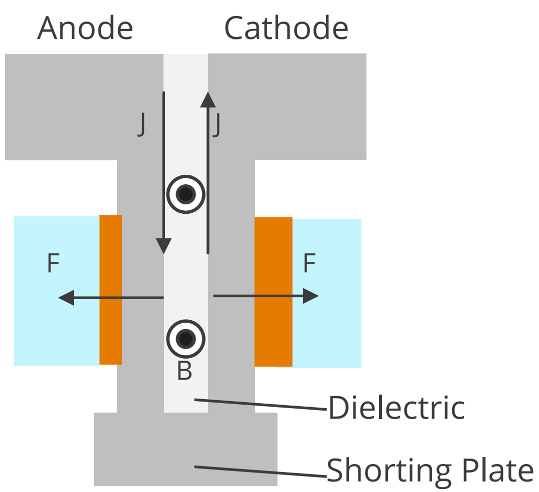

Ramp experiments



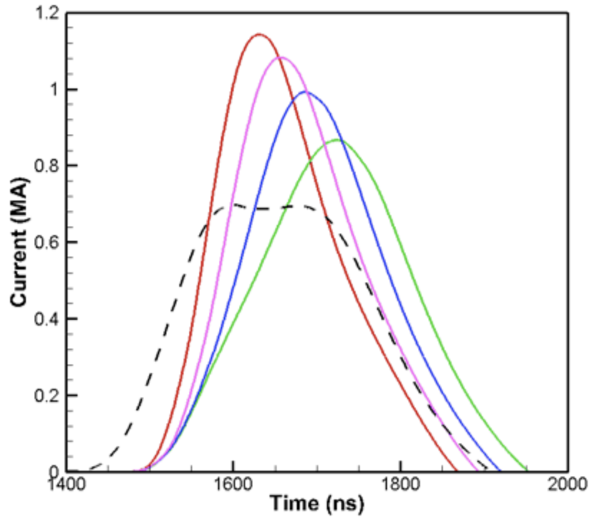
# Pulsed Power Platforms

- Lorentz force is used to drive a panel.
- Capable of tailorable pulse shaping to control current flowing through the panel.
- This gradually increases force of panel, and is known as the 'drive'.
  - i.e. isentropic or ramp loading
- Relevance of wavespeed characteristics
  - Determine thermo. & mech. properties.
- **A successful gun approach will control the imparted drive in a similar fashion!**

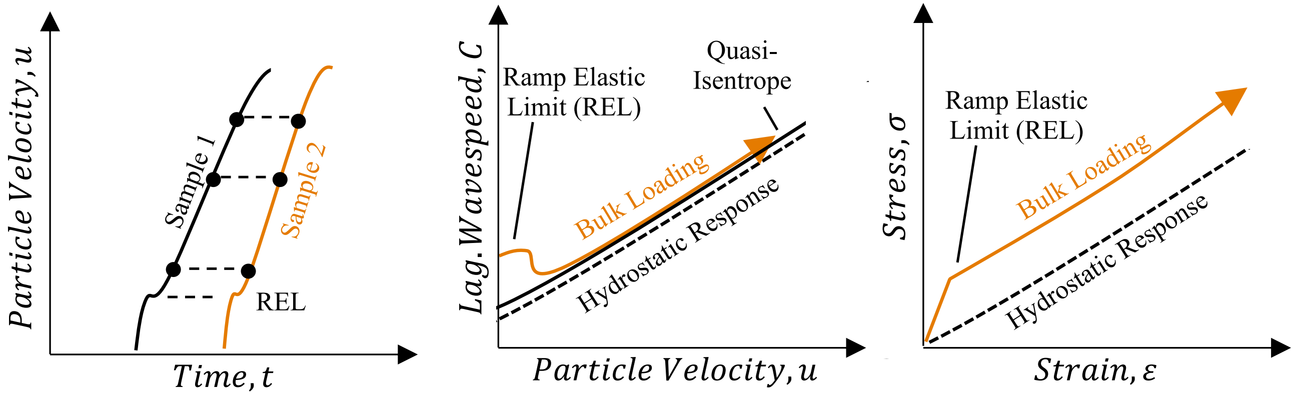
## Example Panel




## Pulse shaping




Stoltzfus, *SAND2017-4952PE*, 2017

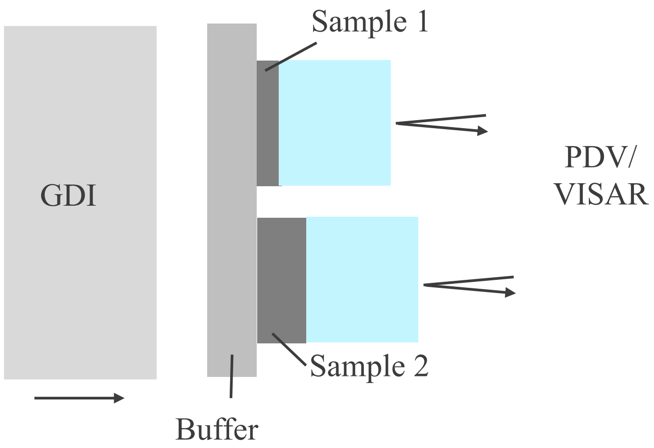


# Gas gun approaches across the literature

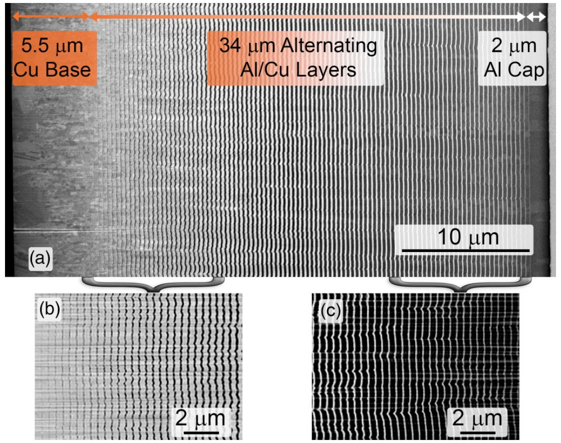
Flavors of Graded Density Impactors:

- Fused quartz:
  - Chhabildas, Alexander, Renou
- Layered GDI:
  - Chhabildas, Yep, Brown, Nguyen
- Bed of Nails (BON):
  - Goff, Cotton, LaLone, Taylor

General Experiment

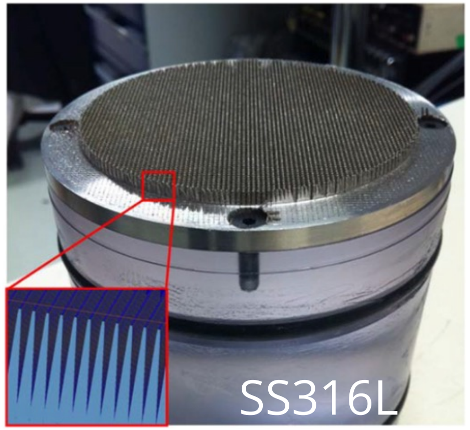



Thin Film GDI

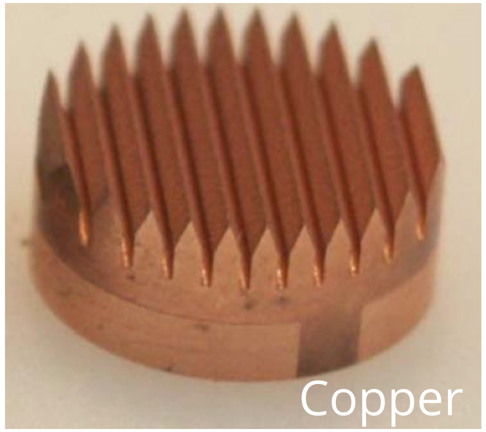



*J. L. Brown, PRB, 2019*

Bed of Nails




*M. Cotton, DYMAT, 2015*

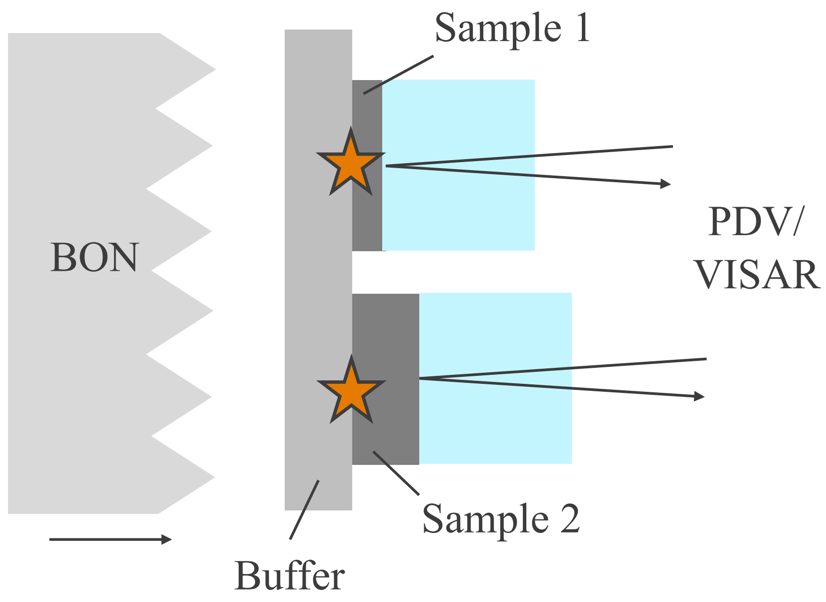


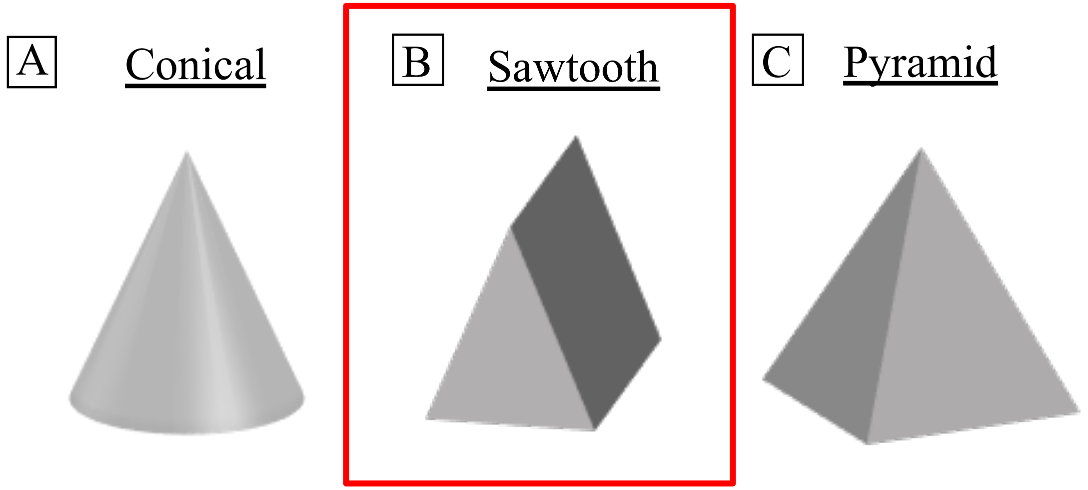

*B. LaLone, DOE/NV/25946—2588, 2020*


*Goff, SCCM, 2020*

# Bed of Nails

- General design:
  - BON, buffer plate, multi sample
- Advantages:
  - True ramp wave, manufacturing, tailorable features, & modeling considerations
- Design features:
  - Materials, impact velocity, buffer plate, nail shape



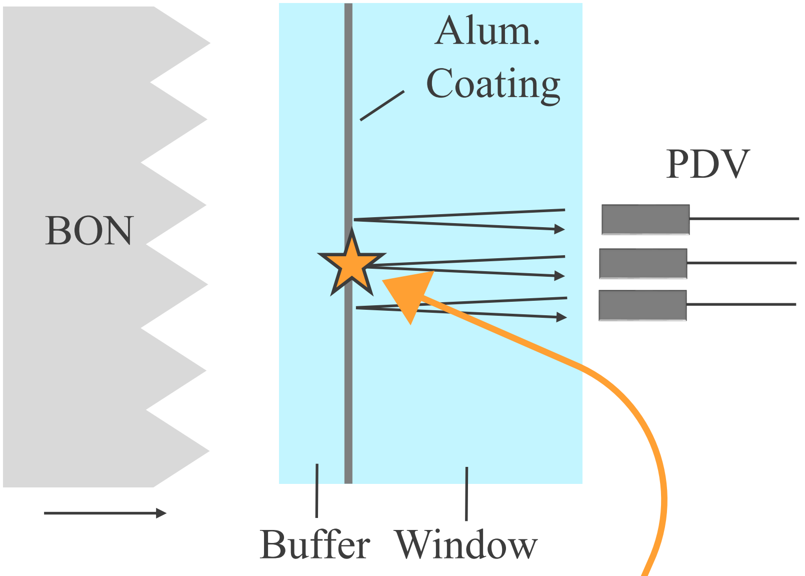

Hypothesis:

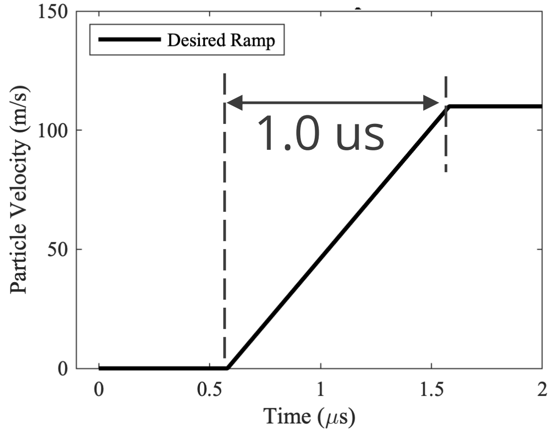
- By fixing materials & dimensions of the buffer plate, an optimization algorithm can be used to tailor the imparted drive.

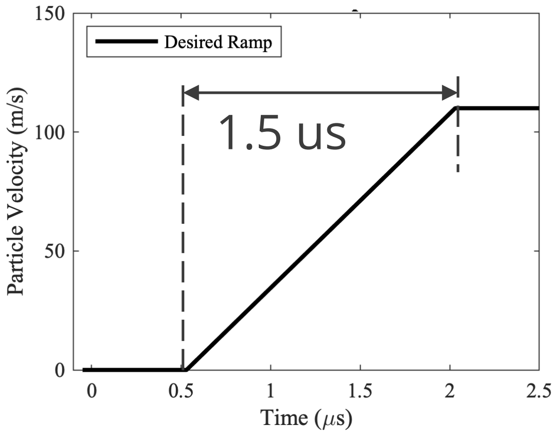
# Design Process

- Experimental configuration:
  - BON: 3D printed Tough PLA
  - Target: LiF Buffer and Window
- Optimization process:
  - Discretization of the nail
  - Genetic algorithms
  - Code implementation
- Print & quality control check:
  - 2D optimized solution, Idealized 3D geometry, & Printed 3D geometry
  - Do they agree?

Configuration




Design criteria:

- 1.0us ramp duration to 1 GPa
- 1.5us ramp duration to 1 GPa

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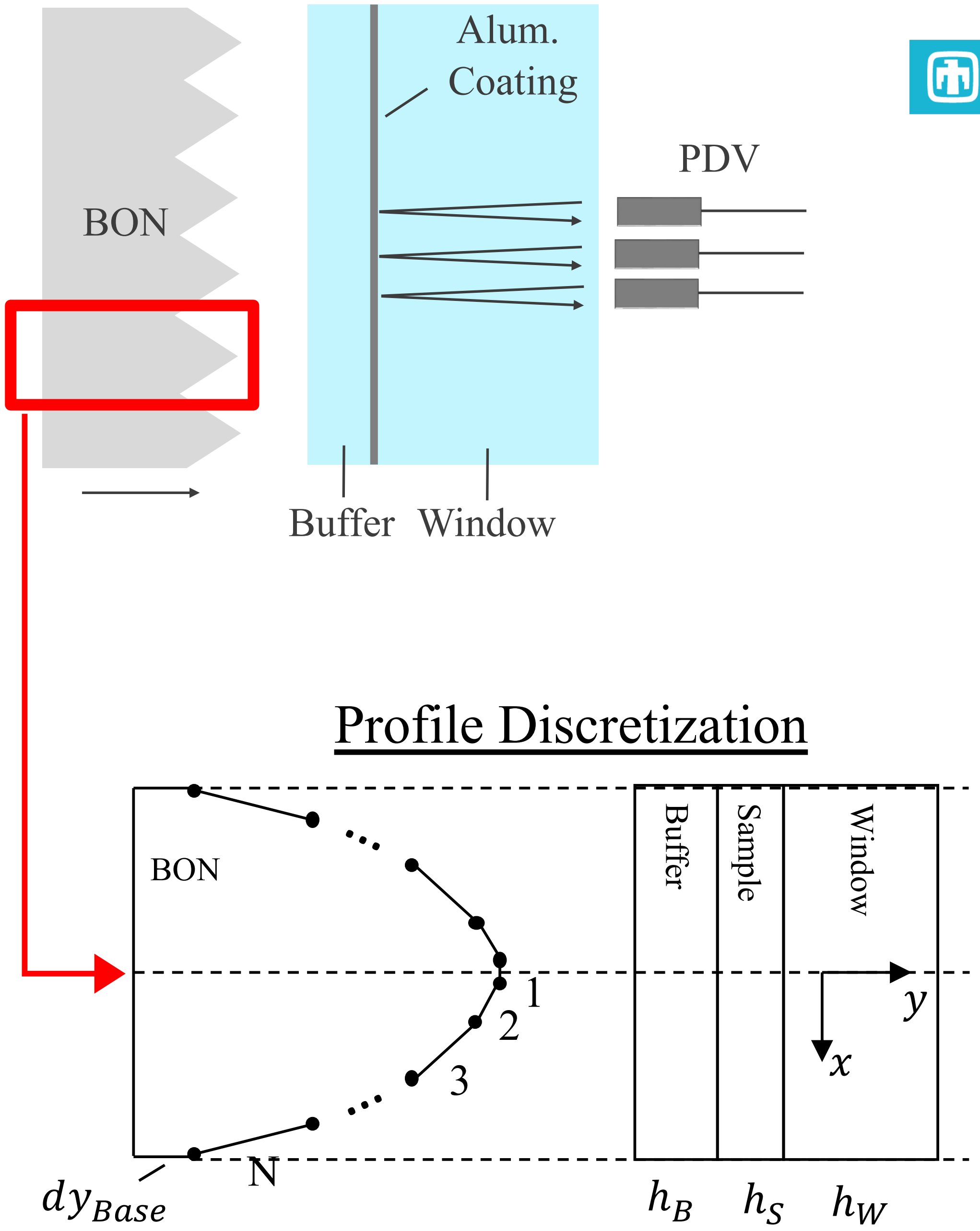

# Design Process

Many cheap 2D simulations of nail shapes to determine optimal nail profile for prescribed drive condition at 2mm.

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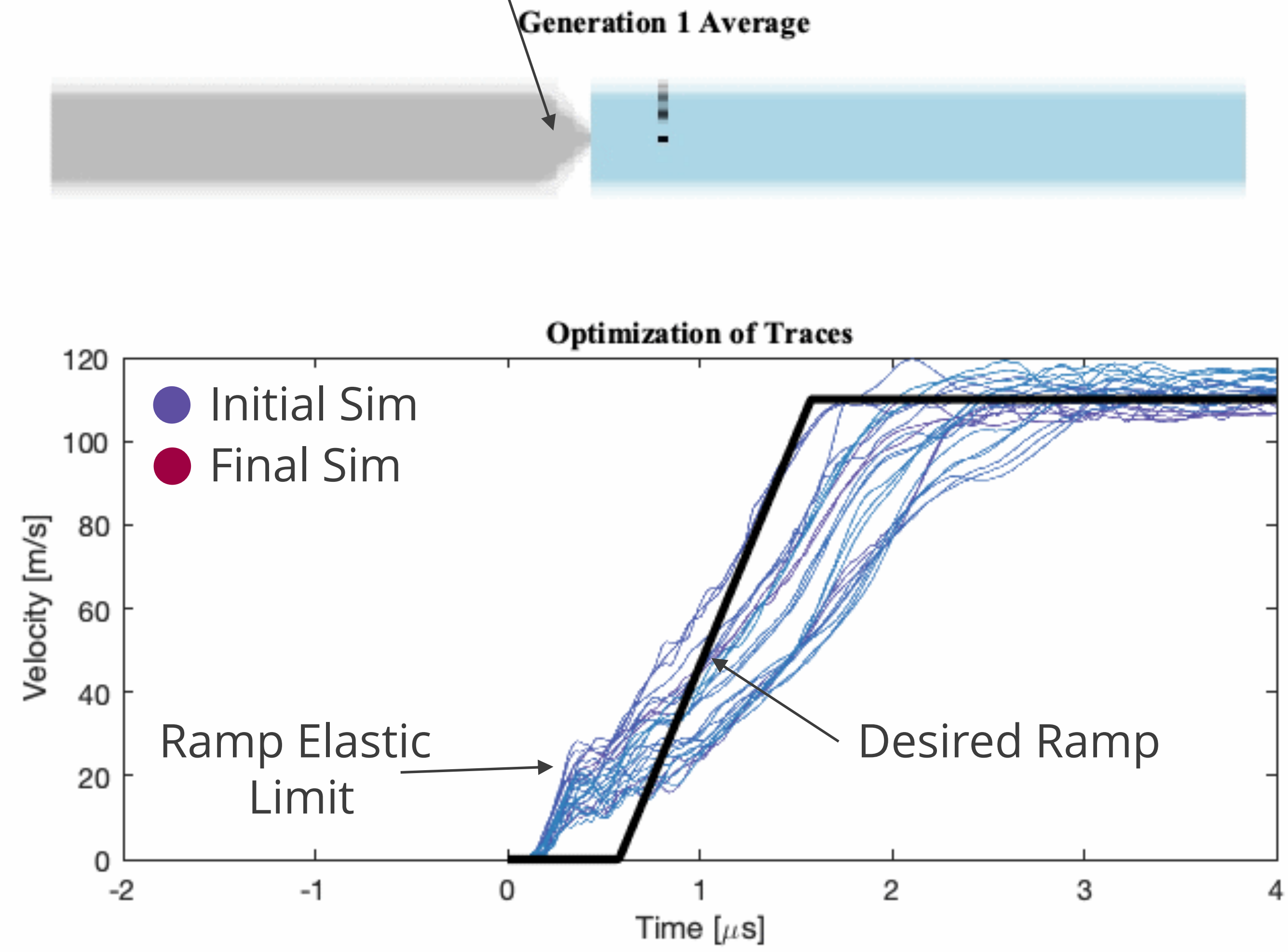

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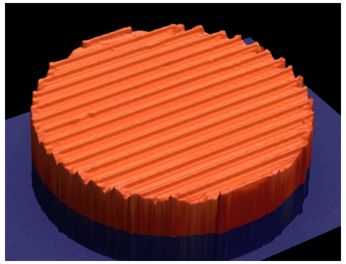
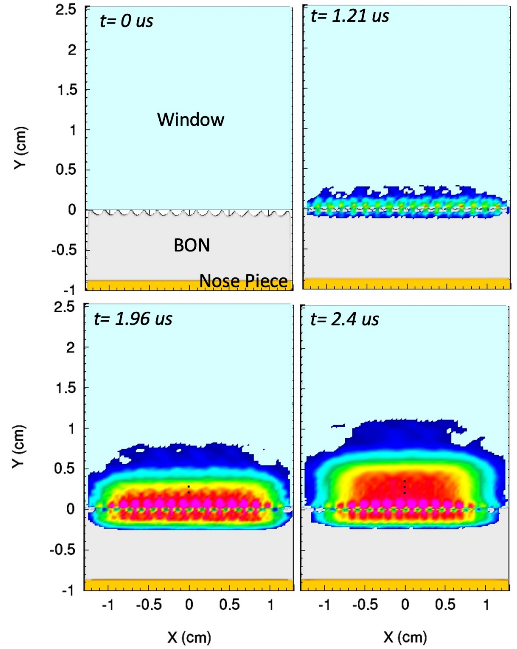
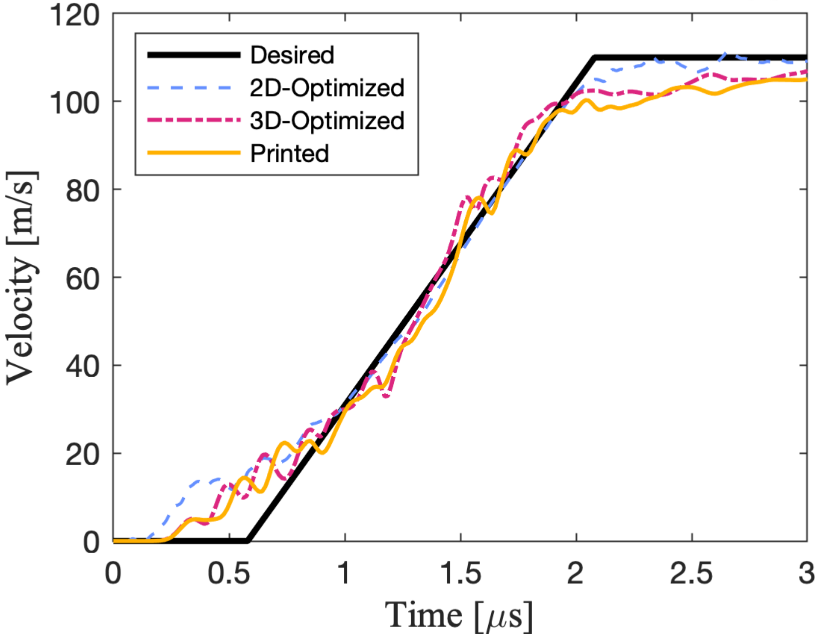
Print

Scan



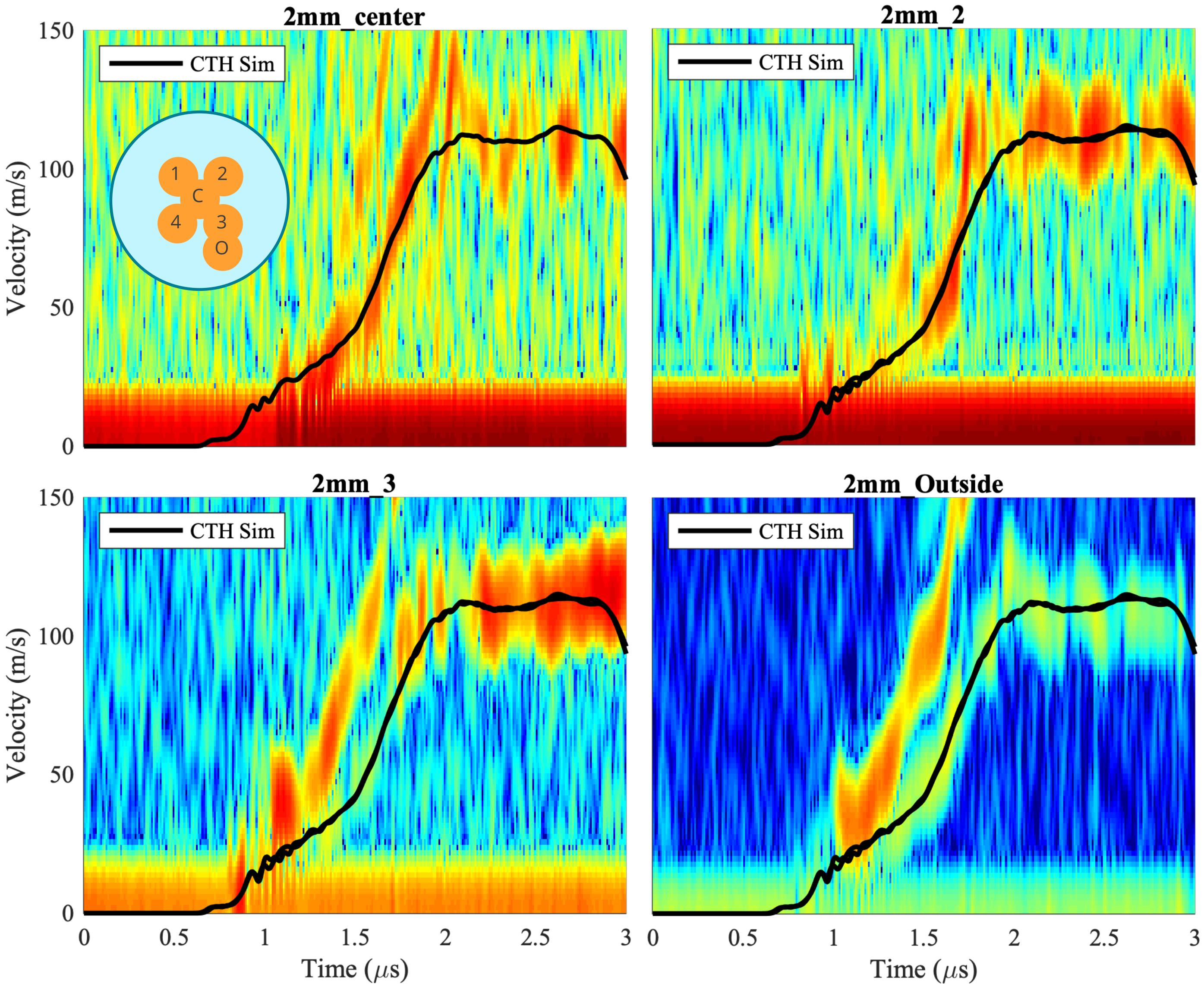
Sim



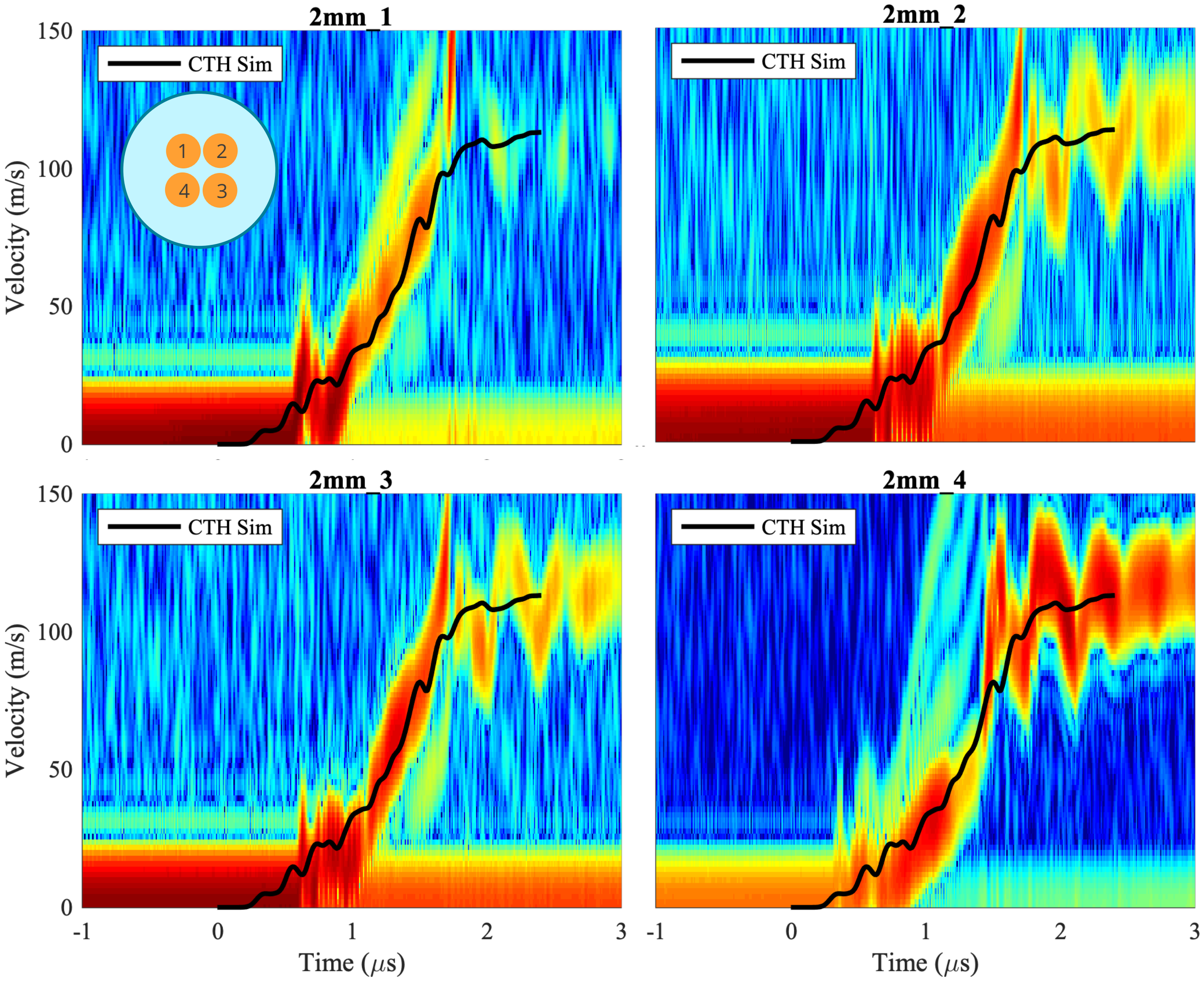
# Results – 1.0 $\mu$s Ramp

- Algorithm was used to design a BON with a 1.0 $\mu$s ramp.
- Ramp elastic limit in LiF
- Decent agreement between simulations and experiment.
- Some heterogeneities in wave profile.
- Viscous effects at peak.
- Oscillations in wave structure about peak stress.



# Results – 1.5 $\mu$s Ramp

- Algorithm was used to design a BON with a 1.5 $\mu$s ramp.
- Decent agreement between simulations and experiment.
- Some heterogeneities in wave profile.
- Viscous effects at peak.
- Oscillations in wave structure about peak stress.



# Conclusions

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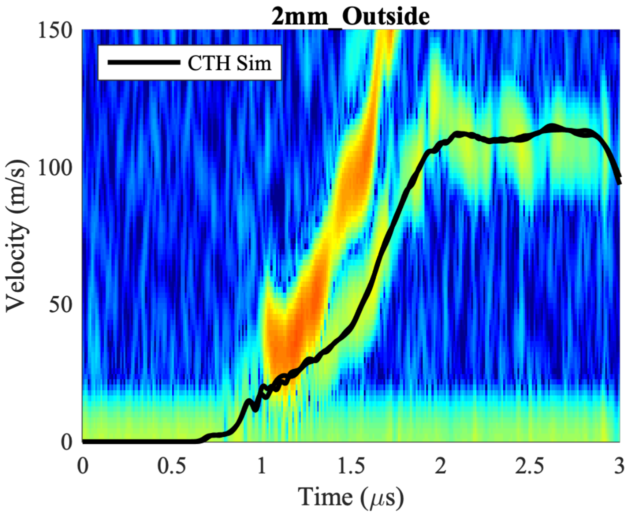
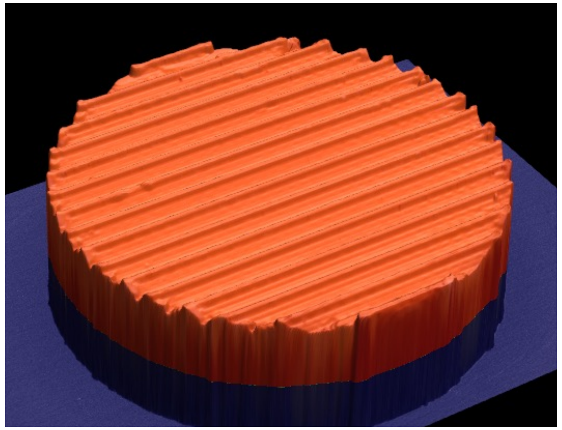
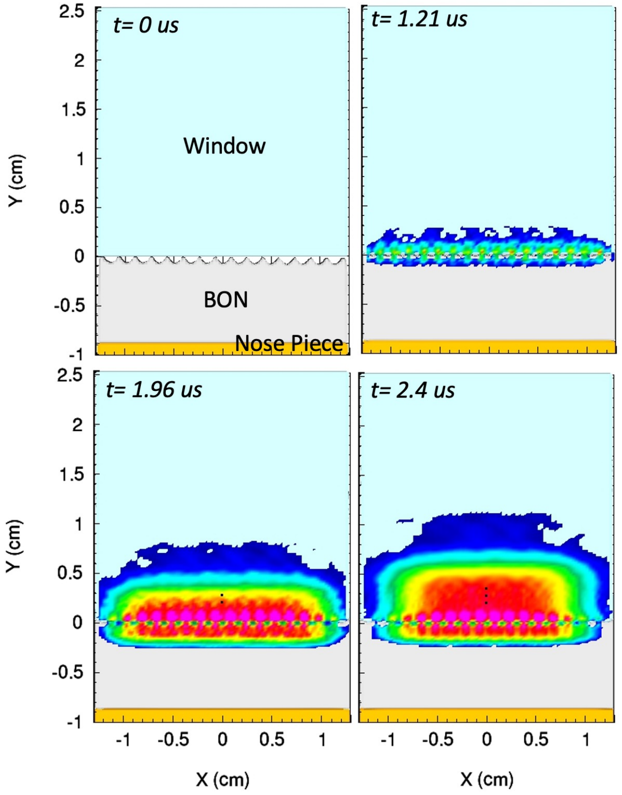
- An optimization algorithm was used to design BON impactors for tailored ramp loading.
- Algorithm is successful at designing the nail shape for desired loading of 1 GPa in LiF.
  - Ramp durations of 1.0 & 1.5us.
- Experiments demonstrate general wave structure desired.
- Further investigation is needed to understand heterogeneities of wave structure and influence of viscosity.





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